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Automatic Transition Prediction for Wings Using a Structured Flow Solver and Linear Stability Analysis

1st AIAA CFD Transition Modeling and Prediction Workshop

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Transition Prediction

- Transition in RANS
 - LST
- Implementation



Flow solver

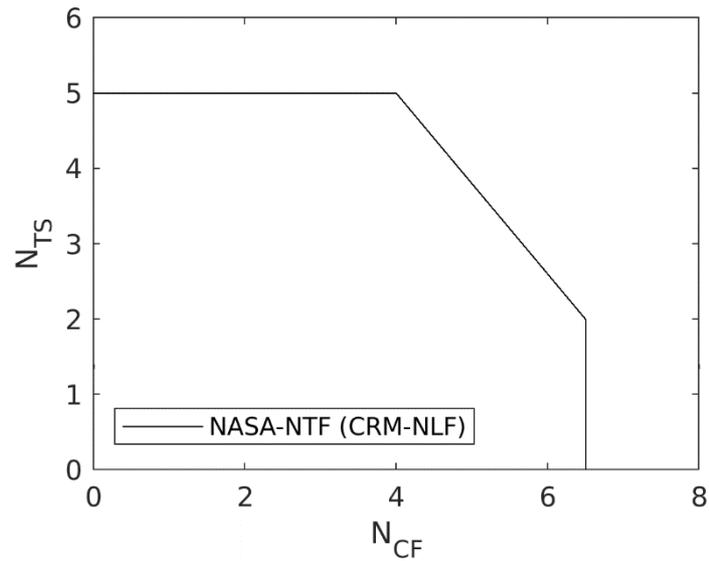
- In-house flow solver ENSOLV
 - (Euler, **RANS**, LSE)
 - cell-centred
 - structured
- Turbulence model used
 - EARSMko2005



Linear Stability Theory

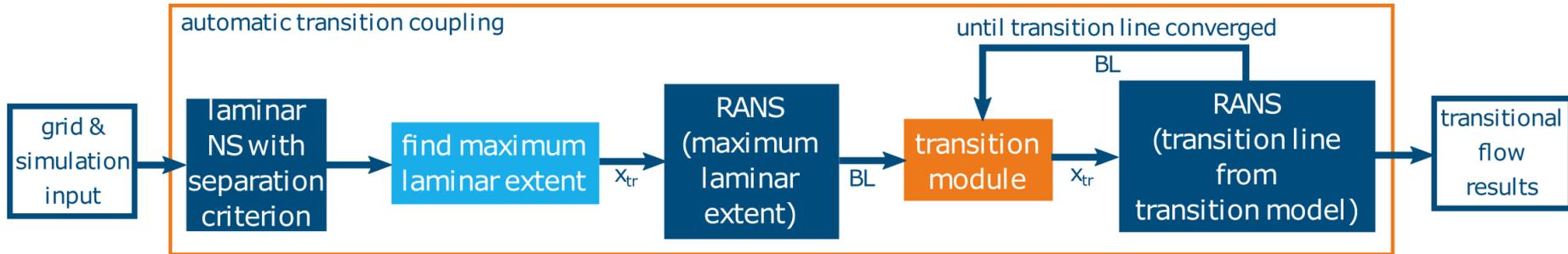
- COSALX (NLR-version of COSAL code [Malik, 1982])
- Compressible computations
- Integration following inviscid streamlines
 - TS: fixed frequency & wave orientation
 - CF: fixed frequency ($=0$) & wavelength

Two-N-factor-strategy



coupling schematic

- Coupling similar to approach by DLR (Krumbein et al. 2009)



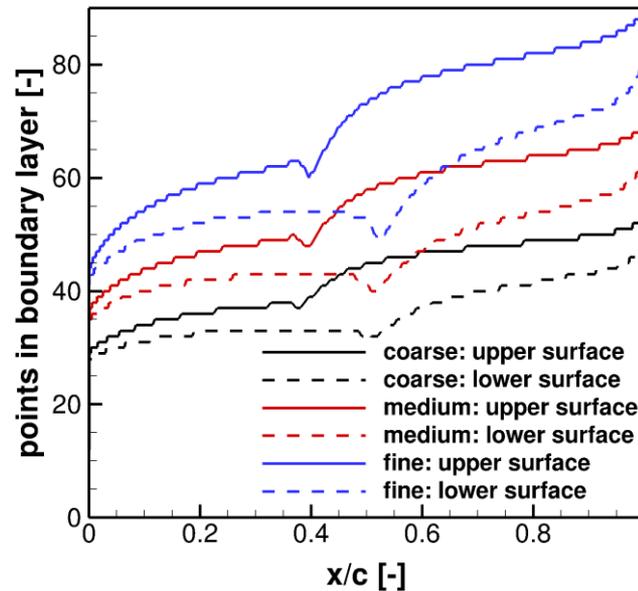
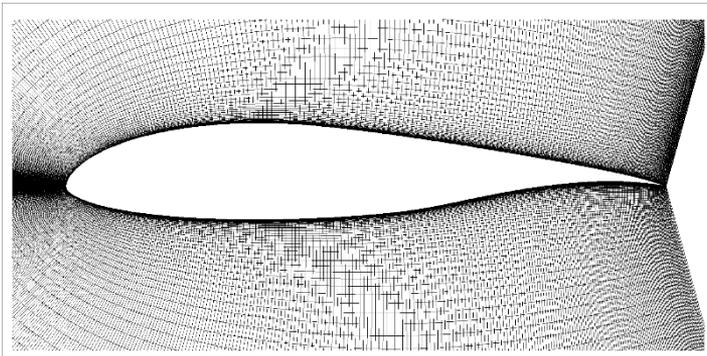
- For more information see:
 - Fischer J., Soemarwoto, B.I., van der Weide, E.T.A. (in press), "Automatic Transition Prediction for Wings Using a Structured Flow Solver and Linear Stability Analysis", AIAA Journal.

Test Cases

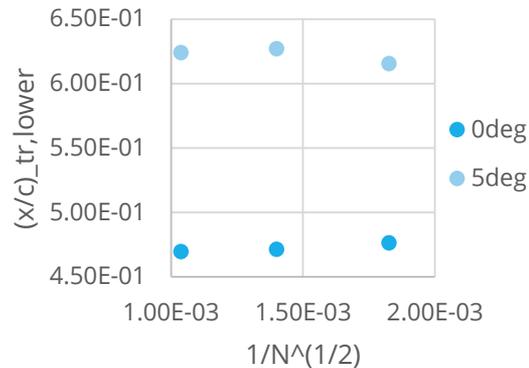
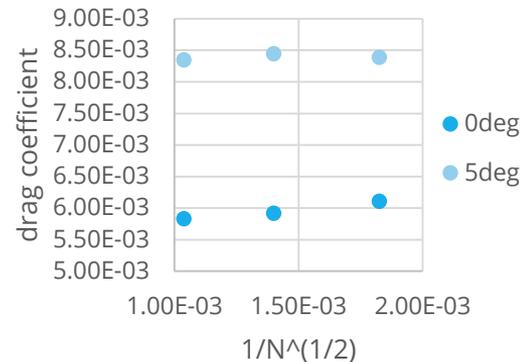
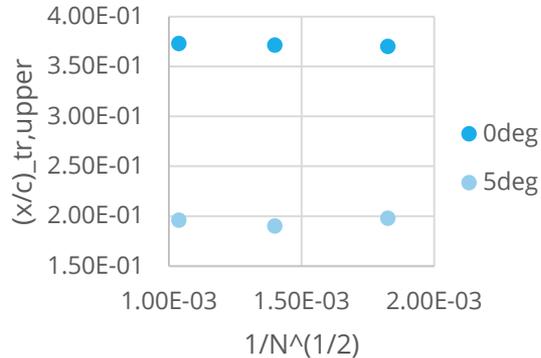
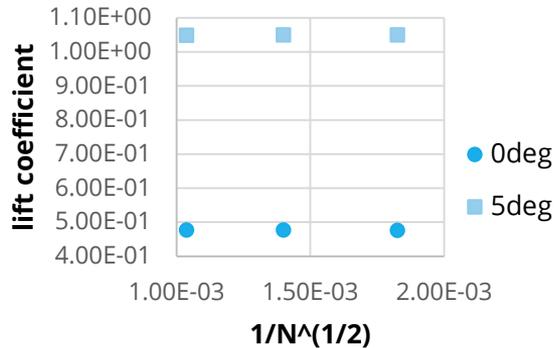
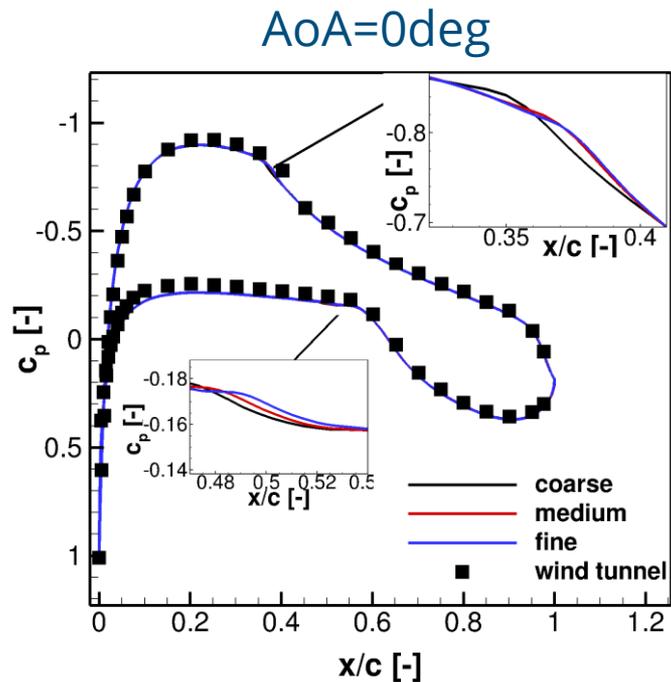
- NLF(1)-0416
- NASA LaRC CRM-NLF

NLF(1)-0416

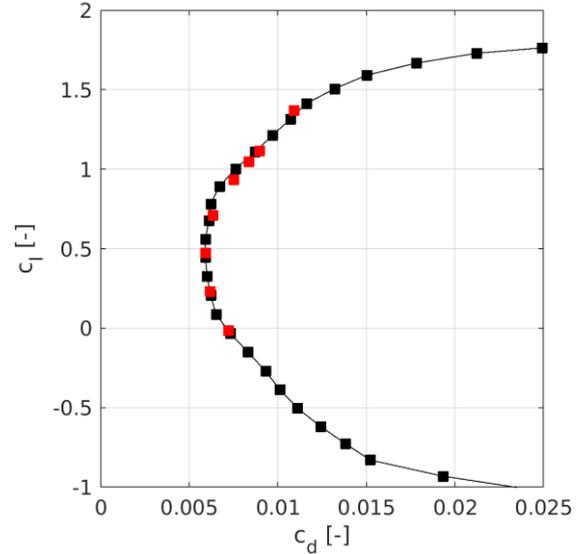
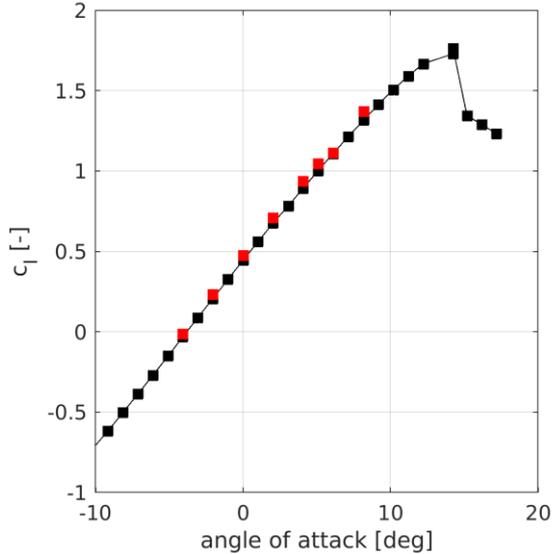
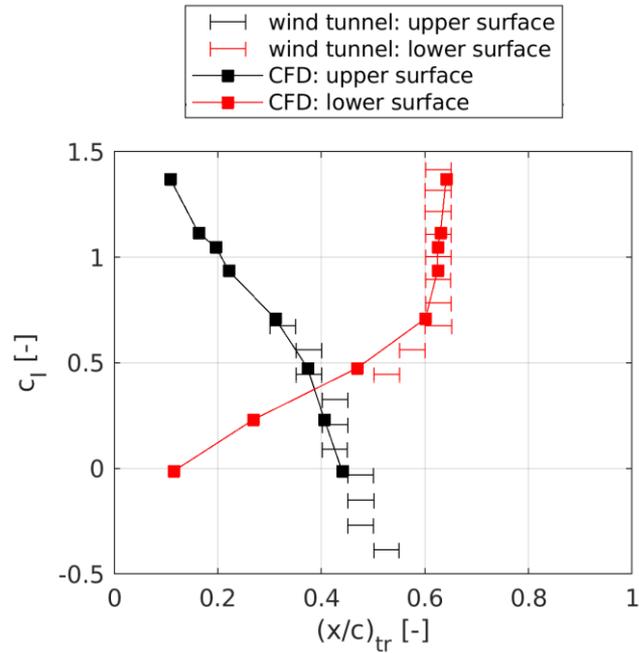
- In-house generated structured meshes



NLF(1)-0416 | grid convergence

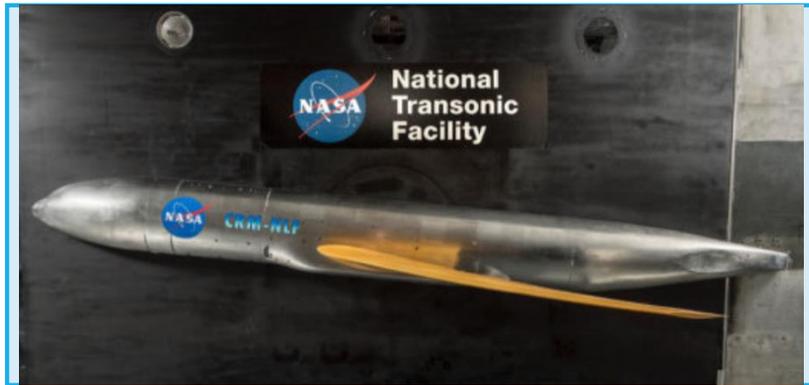


NLF(1)-0416 | results (medium grid)

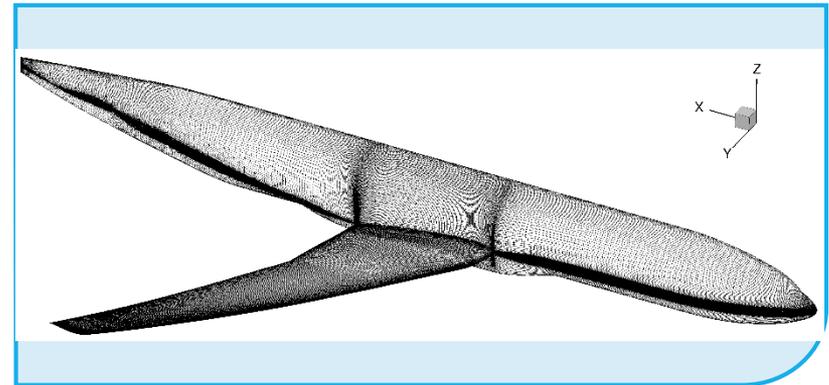


NASA LaRC CRM-NLF

- $Re = 15.0 \cdot 10^6$, $Ma = 0.86$, $\alpha = 1.5^\circ, 2.0^\circ, 2.5^\circ, 3.0^\circ$
- In-house generated structured meshes
 - Medium: 348 spanwise, 480 chordwise, 60-80 wall-normal cells in lam. BL
 - Coarse: 40-60, fine: 80-100 wall-normal cells in lam. BL

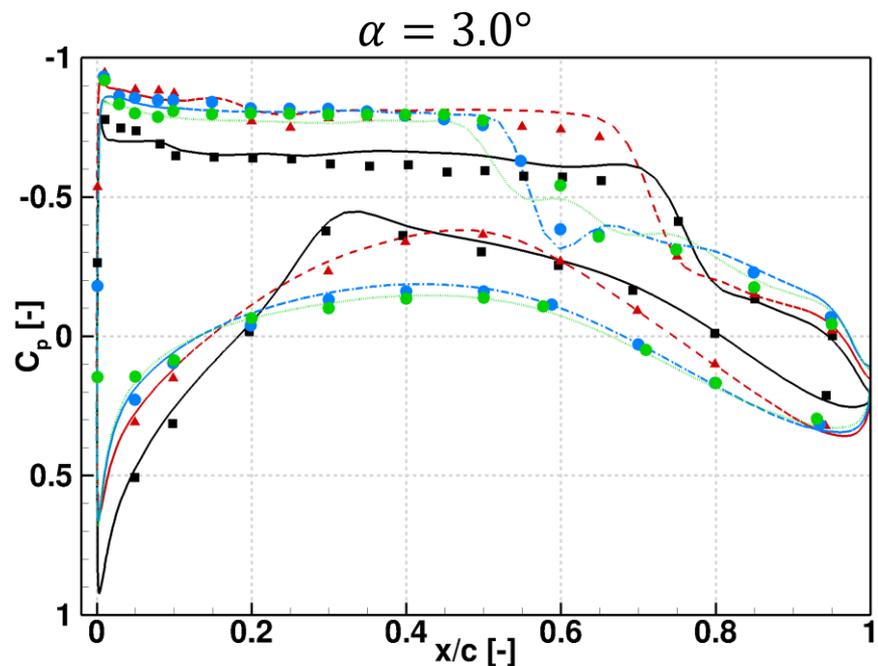
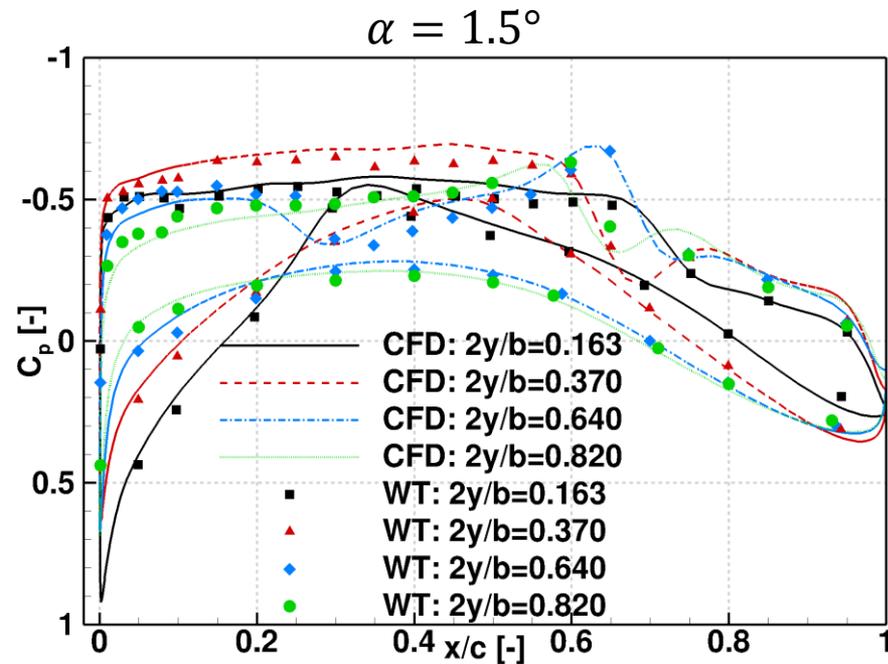


(AIAA, 2020)

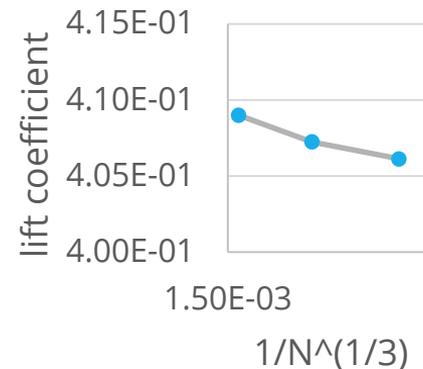
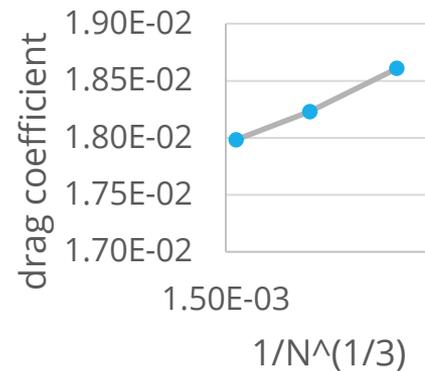
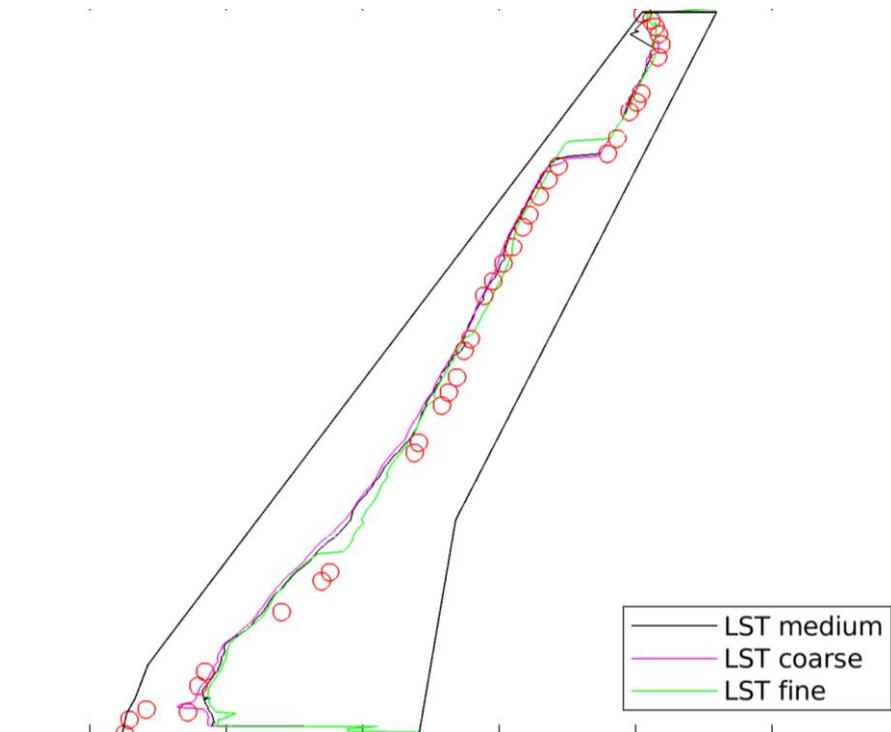


CRM-NLF | pressure distributions

Mach & alpha shifts ($\Delta Ma = -0.003, -0.05^\circ \leq \Delta\alpha \leq -0.2^\circ$)



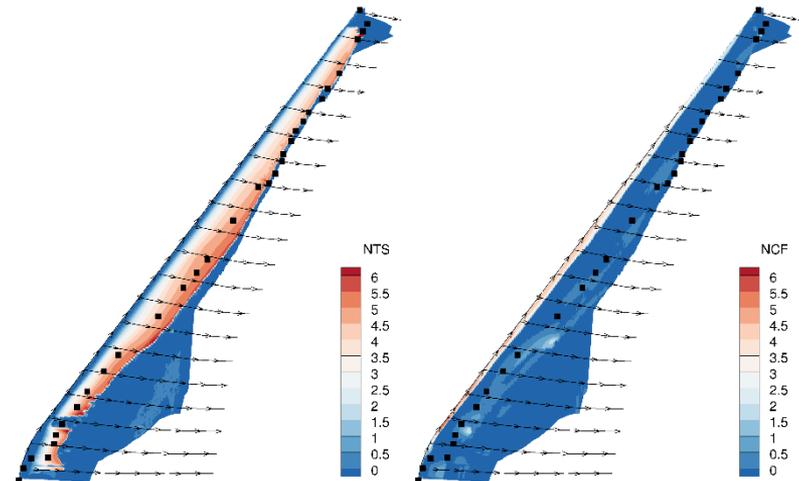
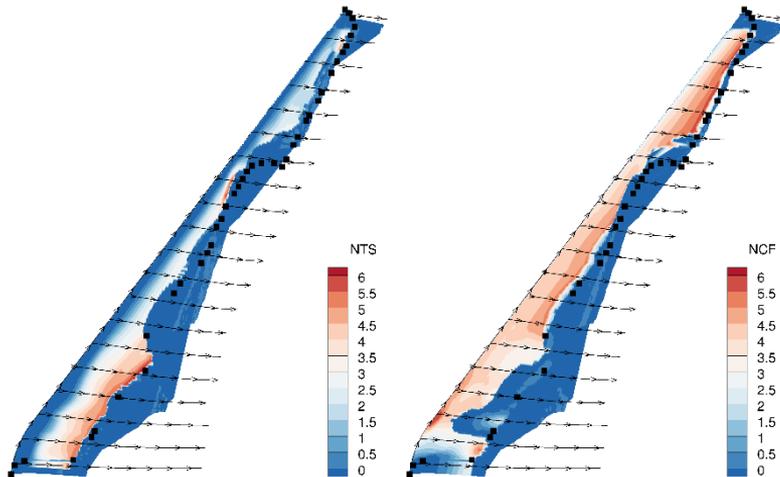
CRM-NLF | grid convergence



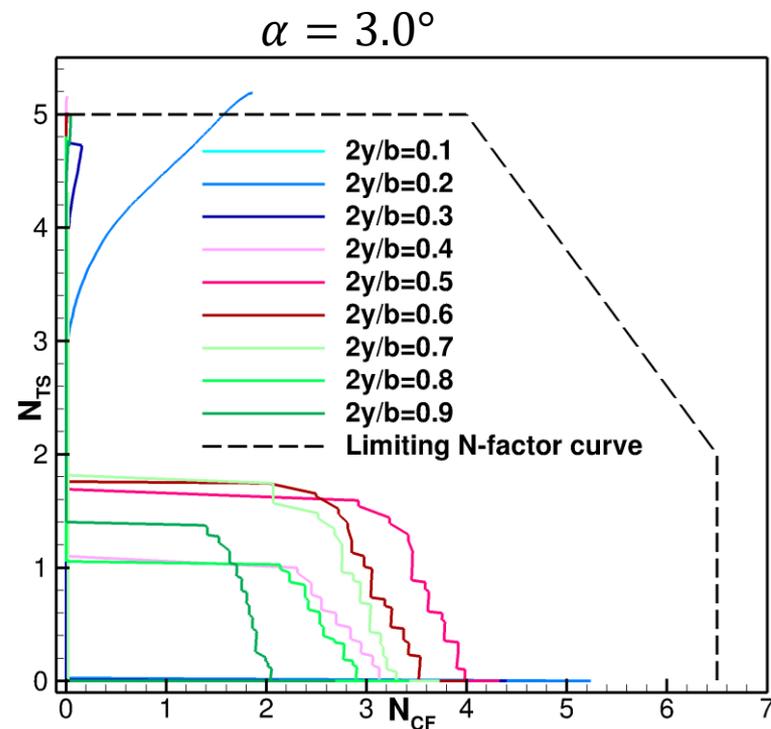
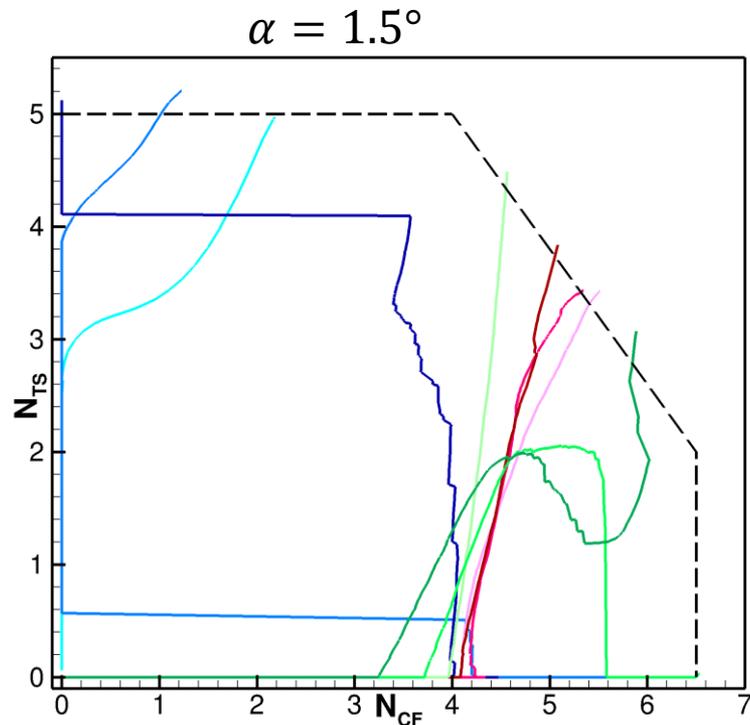
CRM-NLF | N-factor contours

$\alpha = 1.5^\circ$

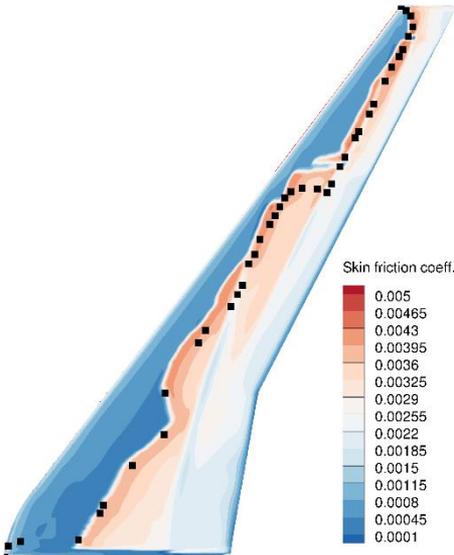
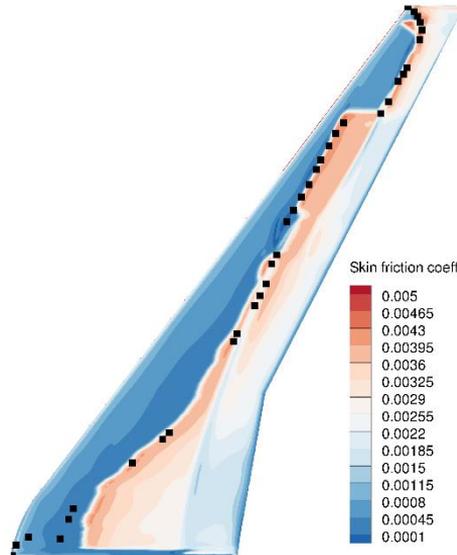
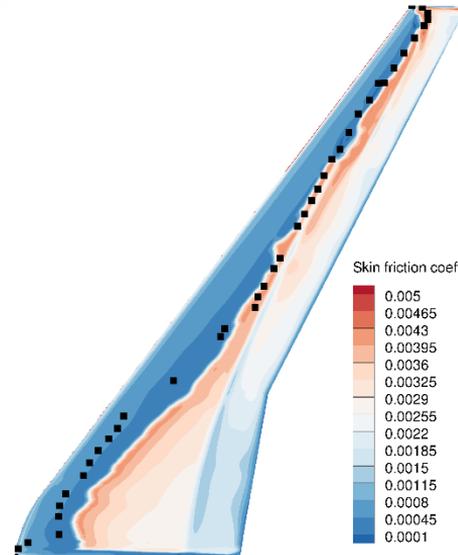
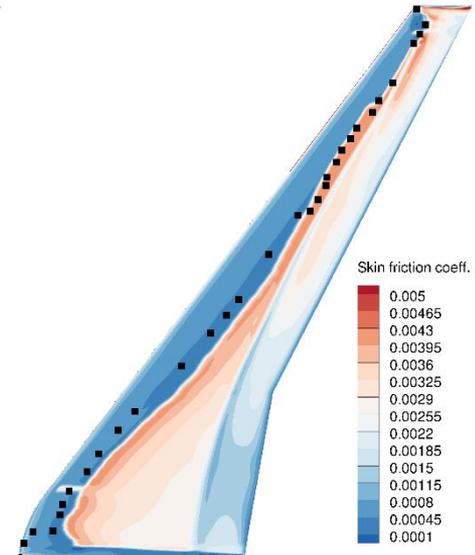
$\alpha = 3.0^\circ$



CRM-NLF | Modes of transition

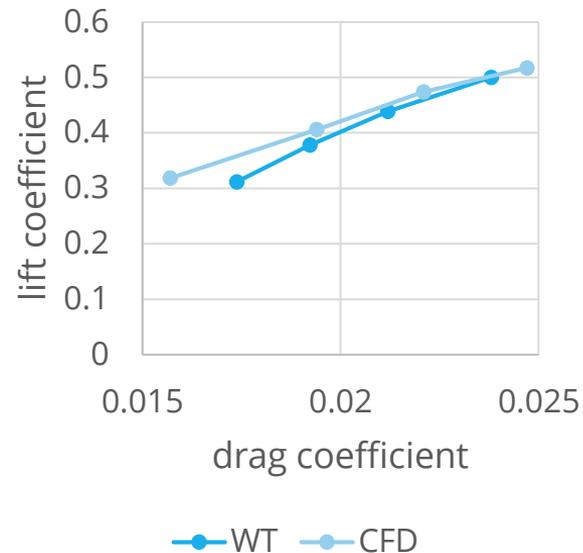
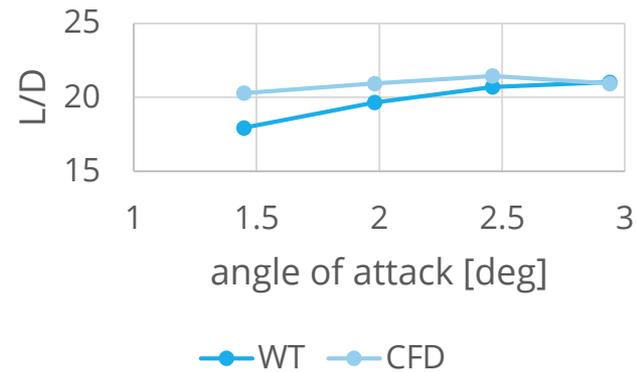
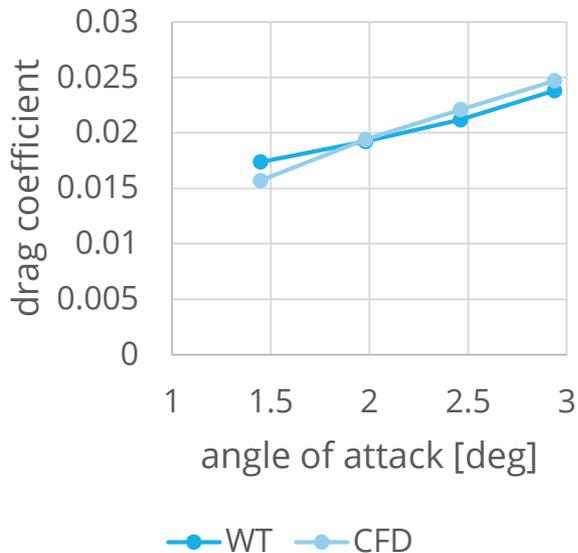
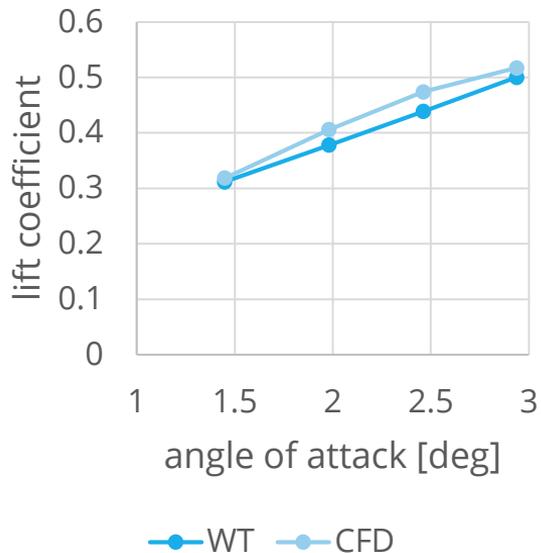


CRM-NLF | Numerical vs. experimental results

 $\alpha = 1.5^\circ$

 $\alpha = 2.0^\circ$

 $\alpha = 2.5^\circ$

 $\alpha = 3.0^\circ$




CRM-NLF | force coefficients



Conclusion



Summary

- Successfully implemented an automatic coupling between RANS & LST
- Demonstrated transition prediction capability on two representative test cases
 - NLF(1)-0416 wind-tunnel results are well reproduced
 - CRM-NLF transition fronts are fairly well predicted
 - Grid sensitivity less pronounced on CRM-NLF than on previous sickle wing test case due to shock-terminated laminar extent
 - Force coefficients less accurate (cl-cd-graph shows good agreement for design loads of mesh->model deformation?)

References

Krumbein, A., Krimmelbein, N., and Schrauf, G., “Automatic Transition Prediction in a Hybrid Flow Solver - Part 1: Methodology and Sensitivities,” *Journal of Aircraft*, Vol. 46, No. 4, 2009, pp. 1176–1190. <https://doi.org/10.2514/1.39736>.

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Malik, M. R., and Orszag, S. A., “Efficient computation of the stability of three-dimensional compressible boundary layers,” *AIAA Paper 1981-1277*, 1981. <https://doi.org/10.2514/6.1981-1277>.



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